University of Alberta Library
0 1620 3069164 4

For Reference

NOT TO BE TAKEN FROM THIS ROOM

Library Copy

A STUDY OF PARENTAL LINES AND BULK PROGENIES FROM SINGLE AND COMPOUND CROSSES IN WHEAT AND BARLEY

Douglas K. Taylor

Department of Field Crops

University of Alberta

Ex libris
universitatis
albertaensis

Digitized by the Internet Archive
in 2018 with funding from
University of Alberta Libraries

https://archive.org/details/studyofparentall00tayl

A STUDY OF PARENTAL LINES AND BULK PROGENIES FROM SINGLE AND COMPOUND CROSSES IN WHEAT AND BARLEY

Douglas K. Taylor
Department of Field Crops

A THESIS
submitted to the University of Alberta
in partial fulfilment of the
requirements for the degree of
MASTER OF SCIENCE

Edmonton, Alberta
April, 1943

Thesis
1943
#19

TABLE OF CONTENTS

	Page
Introduction	1
Literature review	3
Methods	7
Experimental results	13
Greenhouse: F_1 multiple cross test	13
Field: Summary of F_2 and F_3 bulk hybrid yield tests	15
Heterosis in single and multiple hybrid populations	24
Yield	24
Earliness	40
Height	43
Weight per bushel	45
Protein content	46
Genetic relation and heterosis	53
Combining ability of the parents	56
Discussion	58
Summary	61
Acknowledgements	64
References	65

Table of Contents

Introduction 1

Literature review 3

Methods 7

Theoretical results 14

Discussion 22

Conclusion 30

Summary 31

Bibliography 32

Appendix 35

A STUDY OF PARENTAL LINES AND BULK PROGENIES FROM SINGLE AND COMPOUND CROSSES IN WHEAT AND BARLEY

Douglas K. Taylor

INTRODUCTION

With hybridization playing a major role in the production of new cereal varieties, it has become important to know more about the behavior of hybrid populations. The plant breeder has found that certain crosses yield a higher proportion of desirable segregates than others. It would therefore be valuable to him to be able to predict for any cross the probability of obtaining a high proportion of desirable segregates.

An approach to this subject has been made by a few workers (11, 12, 13, 14) who have studied the yielding ability of hybrid material in early generations. Their results suggest that yield tests of bulk populations in the F_2 and F_3 generations might be used as a basis for discarding crosses which eventually will give a low percentage of high-yielding segregates. With the increased use of the bulk method of handling hybrid material, where selection is delayed until a late generation, the ability to discard the poorer crosses in an early generation would be a valuable aid to the plant

A Study of Learning Style and Test Anxiety

[illegible] as a Function of Learning Set

Under the Direction

Douglas C. Taylor

Abstract

The investigation studied a major issue in the [illegible] of the normal curve. In the normal distribution, [illegible] the mean there [illegible] of highly [illegible]. The [illegible] theorem [illegible] [illegible] [illegible]

breeder.

That certain varieties have a higher combining value than others is a fact now established. Some varieties are good parents as judged by their ability to transmit high yield and quality to their progeny. Much has been done along this line in the production of hybrid corn. Similarly, it would be of great value to the cereal plant breeder to know which of his parental varieties consistently transmit high-yielding ability to their offspring.

The phenomenon of hybrid vigor complicates any study of bulk populations in early generations, and its expression in crosses is found in varying degrees of intensity. It is generally accepted that hybrid vigor can be accurately measured by a study of the yields of the hybrid population in comparison with the parents. Knowledge of the amount of heterosis to be expected is important in the study of the yields of early generation hybrids.

It was hoped that the present study would show the behavior of hybrid material in the F_2 and F_3 generations, particularly in comparison with the parents. Many of the hybrids were multiple crosses and the results of these compound matings were of special interest. It was thought that this study might give a preliminary evaluation of the various crosses as a source of future superior selections. Finally it was hoped that some information could be gained in regard to the combining ability of the parents, since such knowledge would be an important contribution to the planning of future crossing programs.

answer.

LITERATURE REVIEW

The phenomenon of hybrid vigor has long been recognized. In cereal crosses, heterosis manifests itself in many ways, but since this study has been confined to days to head, days to mature, height of plant, yield of grain, weight per bushel, and protein percentage, the literature review has also been confined to these factors.

East (4) points out that yield is the result of the operation of the plant as a whole and is therefore considered a reliable estimate of the amount of heterosis. Engledow and Pal (7) and Rosenquist (17) with wheat, Coffman and Wiebe (3) with oats, and Immer (14) with barley have all shown that F_1 hybrids on the average give higher yields than the parental average. Unpublished data by Jenkins (15) show that wheat crosses in a replicated yield test of spaced F_1 plants in the field gave on the average a 14 per cent increase over the parental average. However, the F_1 generation is rather unsatisfactory for yield determinations, owing to the cost of producing enough hybrid seed for an adequate test and because the results can usually be expressed only in terms of plant yield.

Yield tests of F_2, F_3, and F_4 populations are more satisfactory, and several workers have attempted to determine the residual hybrid vigor exhibited by these generations. Coffman and Wiebe (3) in an unreplicated rod-row test in 1938

found that F_2 populations outyielded the average of the parental varieties in three out of four oat crosses studied.

In 1940, Harrington (13), using replicated half-rod-row yield trials of ten unselected F_2 wheat hybrid bulk populations, reported that all but two yielded significantly more than the mean of the parental varieties. In six F_3 crosses only one, Reward x Hope, yielded significantly more than the parental average, and the two crosses involving Quality yielded significantly less. Replicated plot tests of purified F_6, F_7, and F_8 lines selected for high yield and agronomic characteristics showed the Reward x Hope combination to be particularly valuable. On the other hand, selected lines from the two Quality crosses were definitely unpromising. Harrington suggest therefore that bulk F_2 yield trials may be used to indicate the potential yield possibilities of a cross.

Harlan et al (11) carried 379 barley crosses separately in unselected bulk populations for seven years and recorded the yields of single ten-foot rows. Yields of pedigree crosses before selection gave a sound indication of the crosses from which high-yielding segregates might be expected. Low-yielding crosses could have been discarded without loss on the basis of their preselection yields.

Immer (14), with six barley crosses, compared the yields of unselected bulk hybrids with the parents in the F_2, F_3, and F_4 generations. The average yield of the six crosses in the F_2 and F_3 for an average of two years exceeded

the mean of the parents by 24 and 13 per cent, respectively. The F_4 showed an average increase of five per cent over the parental average as the result of one year's test. This represented a decrease in hybrid vigor with the increasing homozygosity of the successive generations. Although unsupported by any data on yield results of selections of these crosses, Immer suggests that yield trials in early generations may be used for discarding certain crosses, since the proportion of high-yielding genotypes in low-yielding crosses will be less than in crosses with a higher average yield.

Harlan et al (11) have established that certain varieties are more valuable as parents and produce an unusually high percentage of superior selections in their offspring, while other varieties give very few high-yielding segregates. Some varieties that had not been sufficiently promising in nursery tests to be grown in plots were found to be superior parents.

As early as 1919, East and Jones (6) stated that earliness often accompanies hybrid vigor. Thompson (19) in 1921, after a study of F_2 and F_3 wheat hybrid populations, found that most F_3 families fell between the parents in maturity although families earlier than the parents were obtained. Florell (8) found a fairly good 3:1 ratio of early and late groups respectively when studying the F_2 generation of wheat hybrids. Clark (1) and later Clark and Hooker (2) found earliness to be dominant or partially dominant when F_2 and F_3 generations were compared with the parents in date of

heading.

Plant height has often been used as a criterion of hybrid vigor. Sax (18) found the average height of F_1 wheat hybrids to be 8 cm. greater than the average of the parents. Griffee (10) reported both an increase and a decrease in height in the F_1 generation. Of 11 crosses, six showed an increase and five a decrease when compared with the parental average. Rosenquist (17) found that of 26 F_1 wheat crosses seven were intermediate and 19 exceeded the tall parent. Heights of F_2 and F_3 hybrid populations of wheat were shown by Clark and Hooker (2) to be intermediate between the heights of parents, but on the average to exceed the parental mean.

Clark and Hooker (2) found that crude protein was inherited in intermediate degrees between wheat parents, through multiple factors. The protein content of grain from F_2 plants was found to be intermediate between that of the parents, and not significantly more variable. A very low correlation existed between F_2 and F_3 lines.

METHODS

During the past few years the cereal breeding program of the Department of Field Crops at the University of Alberta has included the production of many wheat and barley crosses. Not only were single crosses produced but also hybrids involving three, four, five, six, and eight varieties. These multiple crosses in subsequent discussion will be referred to as follows: triple, double, five-variety, six-variety, and eight-variety crosses. The following table gives the construction of the various multiple combinations, using letters for variety names:

TABLE I

Multiple cross	Parent	
	Female	Male
Triple	A x B	C
Double	A x B	C x D
Five-variety	(A x B)(C x D)	E
Six-variety	(A x B)(C x D)	E x F
Eight-variety	(A x B)(C x D)	(E x F)(G x H)

The male and female parents were reversed in some of the barley triple and five-variety crosses for convenience in crossing. All crosses were made using F_1 plants or parental varieties.

In order to study these hybrid populations, the crosses were arranged in three main groups: early wheat hybrids, soft wheat hybrids, and barley hybrids.

The parents involved in the early hard wheat breeding program included five of the earliest maturing varieties and strains available, four standard high-yielding varieties, and two unnamed hybrid lines. The pedigrees of these varieties are given in Table II. Many of the single crosses include one early variety and one relatively late high-yielding variety, and these in turn were used to produce the multiple combinations. It was hoped that some of these single and multiple crosses would be the source of relatively early-maturing, high-yielding segregates.

At the same time as the multiple crosses were being increased in the greenhouse, a preliminary yield test was conducted with the F_1 plants. One standard variety, Canus, and 24 F_1 hybrids were planted in pots with six replicates in an incomplete randomized block arrangement (9). Five plants were grown in each eight-inch pot and these were considered to represent a plot. Notes were obtained on date of heading, date of maturity, plant height, and yield per plant. During the past summer a replicated yield test was arranged in the field, involving a comparison of 52 unselected bulk early wheat hybrids and 11 parental varieties. The hybrids included seven groups of crosses as follows: in the F_2 generation, 14 single, 7 triple, 15 double, 2 five-variety, 4 six-variety, and 1 eight-variety; and in the F_3 generation, 9 single crosses.

TABLE II

Pedigrees of the varieties used as parents in the early and soft wheat hybrid yield tests

Variety	N.S.N.*	C.A.N.**	Parentage
Canus	S-34-1	1260	Kanred (sel.of Crimean) x Marquis (Red Fife x Hard Red Calcutta)
Dicklow	I-33-10		Sel.of Surprise (Chile Club x Michigan Club)
H-29-35			I-28-60 (sib of Thatcher) x Milturum (introduced from Russia)
H-37-30			Caesium (introduced from Russia) x Marquis
Master	I-0-65	1409	Aurora (sel.of Gehun) x Red Fife
Onas	I-33-13		Federation x Tarragon (improved Fife x Taradent's Blue)
Pacific Bluestem	I-33-19		Sel.of White Lammas from Australia
Prelude	I-0-74	1481	Fraser (Alpha x Hard Red Calcutta) x Downy Gehun
Red Bobs	I-0-18	1637	Natural cross with Bobs
Regent 975.6	I-39-22	1938	H-44 (Yaroslav emmer x Marquis) x Reward
Reward	I-35-5	1715	Marquis (Hard Red Calcutta x Red Fife) x Prelude
Thatcher	I-35-9	1820	(Marquis x Iumillo)(Marquis x Kanred)
1515-29.27		1927	482B x Reward
482B	I-38-9	1440	Onega Gehun x Yellow Fife

* Nursery Stock Number

** Canadian Accession Number

The crosses made in an attempt to produce an early soft wheat involved only six parents. These included three soft white spring wheats (Dicklow, Onas, and Pacific Bluestem) and three hard red early spring wheats (Master, Prelude, and 482B) (Table II). The parents were included with 28 F_2 unselected bulk populations in a field yield test. The hybrids included ten single, eight triple, and ten double crosses.

Twelve parental varieties (Table III) differing widely in origin and in agronomic characteristics were used to produce the barley hybrids. The latter included nine single, three triple, six double, two five-variety, and four six-variety crosses. The 24 unselected F_2 bulk hybrids were included with the twelve parental varieties in a field yield test.

All field experiments were of the square lattice design. To obtain the exact number of varieties required by this design in the wheat tests it was found necessary to include "filler" varieties, results from which were included in the analysis but have not been reported in this paper. Six replicates were used in the early wheat test, but only four in the soft wheat and barley tests. Split-replicates helped to make each replicate a compact and uniform unit. Single-row, ten-foot plots were used with the rows one foot apart. Pathways between the banks were four feet wide. Border effect at the ends of the rows was reduced to a minimum by the use of winter rye, planted in a continuous row along the

pathway at right angles and approximately six inches from the ends of the plot rows. The seed was planted with a "V"-belt seeder at the rate of 120 seeds per ten-foot row.

Field notes included date of first head, full head, and maturity, and plant height. Heading and maturity notes could not be obtained on the barley hybrids owing to severe lodging at heading time, and for the same reason date of maturity was omitted in the soft wheat test.

At maturity the plants were pulled, each row was wrapped in a cotton wrapper, tied, and the butt chopped off. Pulling and wrapping helped to avoid mixing and loss of seed. The sheaves were threshed in a small rod-row thresher and the yields recorded. The replicates of each variety or hybrid were bulked and passed through a Boerner sampler. Weight per bushel was obtained and a small sample taken for a protein determination.

TABLE III

Pedigrees of varieties used as parents in the barley hybrid yield test

Variety	N.S.N.*	C.A.N.**	Parentage
Albert (Ottawa 54)	I-30-11	701	Sel.from a natural cross found in Albert
Chevron	I-39-6	772	Sel.from a Swiss variety
Colsess	I-29-1	772	Coast x Success (Nepal x Manchuria)
Lion	I-30-60	723	Introduction from Russia
Newal	H-19-146	1089	O.A.C.21x(Manchuria x Lion)
O.A.C.21	I-36-8	1086	Sel. from Manchuria
Olli	I-37-3		Introduction from Scandinavia
Regal	I-36-4	1865	Manchuriax(Manchuria x Lion)
Titan	H-29-8	1118	Trebi x Glabron (Manchuria x (Lion x Manchuria)
Trebi	I-36-22	1115	Introduction from Black Sea region
Velvet	I-39-10	755	(Manchuria x Lion) x Manchuria
Wisconsin Pedigree 38	I-36-17	1101	Wisconsin 5 (Oderbrucker) x Lion

* Nursery Stock Number

** Canadian Accession Number

EXPERIMENTAL RESULTS

Greenhouse

F_1 multiple cross test

A summary of the results from the early wheat F_1 multiple cross study in the greenhouse is given in Table IV. Analyses of variance indicate significant differences in all the characters studied (Table V). These included yield in grams per plant, days to head, days to maturity, and height in inches. Except in the case of Canus a comparison of the F_1 bulk hybrids with their parents was not possible. A comparison of the relative yielding ability of the various multiple crosses was, however, possible. In the results shown in Table IV, the crosses are arranged in descending order of yield within groups. It is quite evident that within each group the Reward combinations have a tendency to be low yielding. It would seem that although Reward may be valuable for its earliness, its presence in multiple combinations has deleterious effects on the yield of F_1 plants. Reward may not be a suitable early parent to include in multiple crosses where high-yielding segregates are desired.

The greenhouse test gave a fair indication of what might be expected of the F_2 multiple crosses in the field. There was a significant positive correlation between the F_1 greenhouse yields and the F_2 field yields, while the correla-

TABLE IV

Summary of early wheat F_1 multiple cross yield test grown in the greenhouse

	Yield per plant (gms.)	Days to Head	Days to Mature	Height (ins.)
Parental variety				
Canus	1.70	66.6	107.5	36.8
Triple crosses				
(H-30 x 482B) H-35	1.89	61.2	106.2	40.6
(R.B.x 1515) Can.	1.72	62.5	107.8	36.1
(Can.x That.) R.B.	1.64	63.1	107.7	35.6
(H-35 x Rew.) H-30	1.20	65.7	107.1	40.0
(R.B.x Rew.) That.	.72	62.8	106.4	33.7
Double crosses				
(Can.x That.)(H-30 x 482B)	1.86	60.6	105.5	38.0
(482B x That.)(H-30 x Can.)	1.77	60.2	104.5	38.3
(Mas.x Can.)(482B x Rew.)	1.77	58.4	103.3	37.2
(Can.x That.)(R.B.x Mas.)	1.63	60.8	105.6	36.3
(Prel.x 482B)(R.B.x Mas.)	1.44	54.7	100.8	36.8
(R.B.x 1515)(Mas.x Prel.)	1.40	56.6	102.7	36.0
(Can.x That.)(R.B.x Rew.)	1.35	62.4	107.0	35.8
(482B x That.)(R.B.x Rew.)	1.33	58.2	104.5	37.8
(Prel.x 482B)(R.B.x Rew.)	1.26	56.8	102.6	39.0
(482B x That.)(H-30 x Rew.)	1.23	59.5	104.3	38.2
(482B x That.)(H-35 x Rew.)	1.20	59.0	104.2	34.6
(R.B.x 1515)(H-30 x Rew.)	.99	60.7	105.6	35.4
Five-variety crosses				
(H-35 x Rew.)(H-30 x 482B) R.B.	1.63	62.1	107.2	38.6
(H-35 x Rew.)(H-30 x 482B) That.	1.26	61.4	106.0	34.7
Six-variety crosses				
(Can.x That.)(R.B.x 1515) H-30 x Can.	1.49	64.1	107.1	35.3
(H-35 x Rew.)(H-30 x 482B) Can.x That.	1.46	60.7	105.8	37.6
(Can.x That.)(R.B.x 1515) Mas.x Rew.	1.22	58.8	103.5	35.3
(Can.x That.)(R.B.x 1515) H-35 x Rew.	.97	60.8	105.7	35.4
Eight-variety crosses				
[(H-35 x Rew.)(H-30 x 482B)] x [(Can.x That.)(R.B.x 1515)]	1.83	58.4	104.0	37.7
Minimum significant difference	.45	2.5	2.1	2.2

tion coefficients for days to head, days to mature, and height were all highly significant.

TABLE V

Summary of analyses of variance for yield, days to head, days to mature, and height of F_1 multiple crosses grown in the greenhouse

		Mean squares			
			Days to		
Variance due to	D.F.	Yield	Head	Mature	Height
Blocks	29	.1344	15.66**	16.06**	8.17**
Varieties	24	.4678**	38.32**	16.72**	16.17**
Error	96	.1238	3.90	2.62	3.03
Total	149				

** Significant to the 1% point

FIELD

Summary of F_2 and F_3 bulk hybrid yield tests

The following tables are summaries of: (1) the early wheat hybrid test, Table VI; (2) soft wheat hybrid test, Table VII; and (3) the barley hybrid test, Table X. In each table the varieties and hybrids are arranged in descending order of yield within each group of crosses. The analyses of variance for yield are given in Tables VIII, IX, and XI.

TABLE VI

Summary of the results of early wheat hybrid yield test

	Yield (bu.per acre)	Days to 1st head	Days to Full head	Days to Maturity	Height (ins.)	Weight (lb.per bushel)	Protein (%)
Parental varieties							
H-37-30	71.2	64	69	120	59.5	65.0	14.4
Red Bobs	66.9	58	64	111	54.0	65.5	14.5
Canus	60.2	62	65	115	51.7	66.5	15.2
H-29-35	59.7	65	70	119	52.8	67.0	13.1
Thatcher	54.4	59	64	114	49.7	65.0	14.7
Regent	48.8	60	64	113	48.3	65.5	15.3
Master	43.2	54	57	106	49.7	65.0	15.2
482B	42.4	57	61	105	52.2	64.5	17.0
Reward	39.8	58	61	109	48.2	66.5	16.2
Prelude	33.0	54	56	102	45.5	67.0	17.3
1515-29.27	31.2	54	57	107	47.2	66.0	17.5
Single crosses F_2							
H-37-30 x Canus	74.1	62	67	118	55.7	65.5	15.2
H-37-30 x 482B	68.2	58	63	111	59.0	66.0	15.6
Canus x Thatcher	65.4	60	64	113	52.7	65.5	15.3
Red Bobs x Master	65.3	55	59	108	53.0	65.5	14.7
Canus x Red Bobs	65.0	59	64	112	53.0	66.0	14.5
H-37-30 x Reward	64.0	58	64	114	58.0	66.5	15.4
Red Bobs x 1515-29.27	63.7	55	60	108	52.3	66.5	15.6
H-29-35 x Reward	61.1	59	65	114	53.5	66.5	14.9
482B x Thatcher	60.5	56	61	107	54.2	65.0	16.3
Red Bobs x Reward	59.5	57	62	110	53.5	66.0	15.6
482B x Regent	53.8	56	61	106	52.5	65.5	17.2
Master x Reward	49.6	55	57	105	50.2	66.0	15.9
Master x Prelude	49.0	53	56	104	49.8	66.0	16.0
Prelude x 482B	48.0	54	56	104	52.7	65.5	18.0

TABLE VI (continued)

	Yield (bu.per acre)	Days to 1st head	Days to Full head	Days to Maturity	Height (ins.)	Weight (lb.per bushel)	Protein (%)
Single crosses F_3							
H-37-30 x Canus	66.7	62	68	117	54.0	65.5	14.5
Canus x Red Bobs	58.7	60	66	114	53.5	66.0	14.6
Canus x Thatcher	50.7	59	66	114	49.8	65.5	15.4
Red Bobs x Reward	49.6	58	64	112	53.5	66.0	15.1
H-37-30 x 482B	47.7	58	65	113	55.7	66.0	15.2
H-29-35 x Reward	45.6	60	67	117	52.3	67.0	15.1
Red Bobs x 1515-29.27	45.4	56	62	110	52.3	66.0	14.1
482B x Regent	41.6	56	63	111	51.2	64.5	17.2
Master x Reward	36.5	55	59	107	51.0	65.0	15.9
Triple crosses							
(Canus x Thatcher) Red Bobs	69.3	58	64	111	53.3	65.5	14.6
(H-37-30 x 482B) H-29-35	67.7	60	67	115	54.7	67.0	14.4
(H-29-35 x Reward) H-37-30	67.4	60	66	116	56.3	66.0	14.5
(Red Bobs x 1515-29.27) Canus	65.4	57	64	114	54.0	66.5	14.3
(Canus x Red Bobs) Thatcher	63.7	58	64	112	52.7	65.0	14.8
(Red Bobs x Reward) Regent	58.6	57	63	111	52.8	66.0	15.4
(Red Bobs x Reward) Thatcher	56.3	57	63	111	52.2	66.0	15.6
Double crosses							
(482B x Thatcher)(H-37-30xCanus)	68.0	57	63	111	55.0	65.5	15.7
(482B x Thatcher)(H-37-30 x Reward)	65.5	58	64	111	56.7	65.5	15.6
(Canus x Thatcher)(Red Bobs x Master)	63.4	56	62	111	52.5	65.0	14.9
(Canus x Thatcher)(H-37-30 x 482B)	62.6	58	64	113	55.0	65.5	15.6
(Red Bobs x 1515-29.27)(H-37-30 x Reward)	61.9	56	62	112	54.7	66.5	15.9
(482B x Thatcher)(Red Bobs x Reward)	60.0	56	62	110	54.7	65.5	15.4

TABLE VI (continued)

	Yield (bu.per acre)	Days to 1st head	Days to Full head	Days to Maturity	Height (ins.)	Weight (lb.per bushel)	Protein (%)
Double crosses (continued)							
(482B x Regent)(Canus x Red Bobs)	59.2	57	63	108	53.2	65.5	16.1
(H-29-35 x Reward)(H-37-30 x 482B)	58.7	58	64	113	55.2	66.0	15.0
(Master x Canus)(482B x Reward)	58.2	56	62	109	52.8	65.5	15.9
(Canus x Thatcher)(Red Bobs x 1515-29.27)	57.8	56	62	111	51.0	66.0	15.1
(Prelude x 482B)(Red Bobs x Reward)	57.6	55	58	106	54.0	66.5	16.3
(Canus x Thatcher)(Red Bobs x Reward)	57.4	58	63	112	52.3	65.5	15.4
(Red Bobs x 1515-29.27)(Master x Prelude)	56.0	53.	56	104	51.2	66.0	14.7
(482B x Thatcher)(H-29-35 x Reward)	55.2	57	62	110	52.2	65.5	15.7
(Prelude x 482B)(Red Bobs x Master)	54.4	53	57	106	52.3	65.5	16.1
Five-variety crosses							
(H-29-35 x Rew.)(H-37-30 x 482B) Red Bobs	67.0	59	64	113	54.0	65.0	14.5
(H-29-35 x Rew.)(H-37-30 x 482B) Thatcher	57.3	57	64	111	52.2	65.0	15.7
Six-variety crosses							
(H-29-35 x Rew.)(H-37-30 x 482B) Can.x That.	60.6	58	64	112	53.8	66.0	14.9
(Can.x That.)(R.B.x 1515-29.27) H-37-30 x Can.	60.5	59	66	116	54.3	66.5	15.4
(Can.x That.)(R.B.x 1515-29.27) H-29-35 x Rew.	59.7	57	63	112	52.8	66.5	14.7
(Can.x That.)(R.B.x 1515-29.27) Mas.x Rew.	55.2	56	61	109	50.5	65.5	15.3
Eight-variety cross							
[(H-29-35 x Rew.)(H-37-30 x 482B)] x [(Can.x That.)(R.B.x 1515-29.27)]	63.8	57	64	112	54.0	66.0	15.4
Minimum significant difference	6.0						

(continued)

TABLE VII

Summary of the results of soft wheat hybrid yield test

	Yield (bu.per acre)	Days to 1st head	Days to Full head	Height (ins.)	Weight (lb.per bushel)	Protein (%)
Parental varieties						
Dicklow	82.7	66	70	55.8	60.5	11.2
Pacific Bluestem	75.0	69	74	62.2	63.0	11.5
Onas	74.4	63	68	50.0	62.0	11.6
Master	45.4	52	55	49.5	64.5	14.6
482B	37.1	54	59	54.0	65.0	16.9
Prelude	34.2	51	55	47.2	67.0	16.4
Single crosses						
Dicklow x Onas	82.9	63	68	55.2	62.0	11.7
P.B.S. x Onas	81.9	62	68	60.2	63.5	12.3
Onas x Prelude	80.2	54	60	52.8	66.0	14.0
P.B.S. x Prelude	77.3	55	62	59.2	66.5	13.8
P.B.S. x 482B	74.2	57	63	60.0	65.0	13.9
Dicklow x 482B	73.4	59	64	57.5	63.5	13.8
P.B.S. x Dicklow	66.6	64	72	59.2	62.0	11.5
Onas x 482B	60.6	56	62	54.5	65.0	14.3
482B x Master	49.6	51	55	53.5	65.0	15.7
Master x Prelude	47.7	51	54	49.8	66.0	15.2
Triple crosses						
(Dicklow x 482B) Dicklow	83.5	62	67	57.5	63.0	12.7
(P.B.S. x Onas) 482B	78.6	55	62	57.0	65.0	14.2
(P.B.S. x Dicklow) Master	76.2	55	62	56.5	64.0	13.5

Table 10. Number of Persons Aged 16 and Over Who Were Employed, Unemployed, or Not in the Labor Force, by Sex, Age, and Color, for the United States: March 1960 and 1959

(Numbers in thousands. Civilian noninstitutional population. Annual averages of monthly figures)

Sex, age, and color	Total			Employed			Unemployed			Not in labor force		
	1960	1959	Change	1960	1959	Change	1960	1959	Change	1960	1959	Change
BOTH SEXES												
16 years and over	112,944	110,806	2,138	66,681	65,746	935	3,852	3,740	112	42,411	41,320	1,091
16 and 17 years	5,911	5,772	139	2,660	2,600	60	1,000	1,000	0	2,251	2,172	79
18 and 19 years	6,911	6,722	189	4,000	3,900	100	1,000	1,000	0	1,911	1,822	89
20 to 24 years	11,000	10,800	200	7,000	6,900	100	1,000	1,000	0	3,000	2,900	100
25 to 34 years	20,000	19,800	200	14,000	13,900	100	1,000	1,000	0	5,000	4,900	100
35 to 44 years	20,000	19,800	200	14,000	13,900	100	1,000	1,000	0	5,000	4,900	100
45 to 54 years	20,000	19,800	200	14,000	13,900	100	1,000	1,000	0	5,000	4,900	100
55 to 64 years	20,000	19,800	200	14,000	13,900	100	1,000	1,000	0	5,000	4,900	100
65 years and over	9,000	8,900	100	2,000	1,900	100	1,000	1,000	0	6,000	5,900	100
MALE												
16 years and over	54,000	53,000	1,000	32,000	31,500	500	2,000	2,000	0	20,000	19,500	500
16 and 17 years	3,000	2,900	100	1,500	1,450	50	500	500	0	1,000	950	50
18 and 19 years	3,500	3,400	100	2,000	1,950	50	500	500	0	1,000	950	50
20 to 24 years	5,000	4,900	100	3,000	2,950	50	500	500	0	1,500	1,450	50
25 to 34 years	10,000	9,900	100	7,000	6,950	50	500	500	0	2,500	2,450	50
35 to 44 years	10,000	9,900	100	7,000	6,950	50	500	500	0	2,500	2,450	50
45 to 54 years	10,000	9,900	100	7,000	6,950	50	500	500	0	2,500	2,450	50
55 to 64 years	10,000	9,900	100	7,000	6,950	50	500	500	0	2,500	2,450	50
65 years and over	4,500	4,400	100	1,000	950	50	500	500	0	3,000	2,950	50
FEMALE												
16 years and over	58,944	57,806	1,138	34,681	34,246	435	1,852	1,740	112	22,411	21,820	591
16 and 17 years	2,911	2,872	39	1,160	1,150	10	500	500	0	1,251	1,222	29
18 and 19 years	3,411	3,322	89	2,000	1,950	50	500	500	0	911	872	39
20 to 24 years	6,000	5,900	100	4,000	3,950	50	500	500	0	1,500	1,450	50
25 to 34 years	10,000	9,900	100	7,000	6,950	50	500	500	0	2,500	2,450	50
35 to 44 years	10,000	9,900	100	7,000	6,950	50	500	500	0	2,500	2,450	50
45 to 54 years	10,000	9,900	100	7,000	6,950	50	500	500	0	2,500	2,450	50
55 to 64 years	10,000	9,900	100	7,000	6,950	50	500	500	0	2,500	2,450	50
65 years and over	4,500	4,400	100	1,000	950	50	500	500	0	3,000	2,950	50

TABLE VII (continued)

	Yield (bu.per acre)	Days to 1st head	Days to Full head	Height (ins.)	Weight (lb.per bushel)	Protein (%)
Triple crosses (continued)						
(Dicklow x Onas) Master	69.9	55	62	54.5	64.0	13.6
(Dicklow x 482B) 482B	69.4	54	61	57.0	64.0	15.0
(P.B.S. x Onas) Master	67.7	55	62	54.2	64.5	13.9
(P.B.S. x Onas) Prelude	64.0	54	61	53.2	66.0	14.4
(Onas x Prelude) Master	62.2	52	58	52.5	65.5	14.3
Double crosses						
(Dicklow x 482B)(P.B.S. x Onas)	82.2	60	65	58.8	63.5	12.9
(P.B.S. x 482B)(Onas x Prelude)	81.6	54	62	57.5	66.0	14.5
(Onas x Prelude)(P.B.S. x 482B)	79.8	55	62	57.8	65.5	13.5
(P.B.S. x 482B)(Onas x 482B)	78.4	54	62	58.5	66.0	14.0
(Onas x 482B)(Onas x Prelude)	78.4	54	61	53.8	66.0	14.0
(Dicklow x 482B)(Onas x 482B)	78.2	56	64	58.2	64.5	13.3
(Onas x Prelude)(Dicklow x 482B)	77.3	55	62	54.2	65.0	13.5
(Onas x 482B)(P.B.S. x Prelude)	75.8	54	62	56.5	66.0	14.1
(P.B.S. x Prelude)(Dicklow x 482B)	70.2	55	63	56.2	65.5	14.0
(482B x Master)(Dicklow x Onas)	68.6	55	62	55.5	65.0	12.7
Minimum significant difference	8.8					

TABLE VIII

Analysis of variance for yield of early wheat hybrid yield test

Variance due to	D.F.	M.S.	F
Blocks	47	4,260.13	4.95**
Varieties	63	17,666.96	20.53**
Error	273	860.68	
Total	383		

TABLE IX

Analysis of variance for yield of soft wheat hybrid yield test

Variance due to	D.F.	M.S.	F
Blocks	23	5,947.04	5.09**
Varieties	35	22,196.25	19.00**
Error	85	1,168.26	
Total	143		

** Significant to the 1% point.

TABLE X

Summary of the results of barley hybrid yield test

	Yield (bu.per acre)	Weight (lb.per bushel)	Protein (%)
Parental varieties			
Newal	110.4	53.5	14.9
Colsess	95.6	43.5	14.5
Albert	95.4	51.0	15.8
Regal	93.0	53.5	14.3
Olli	92.0	52.0	14.6
Wisconsin 38	88.2	52.0	15.1
Titan	86.8	54,5	13.7
Chevron	81.8	56.0	17.4
Trebi	81.2	51.5	14.2
O.A.C.21	76.6	53.5	14.4
Velvet	74.0	53.0	15.7
Lion	58.0	53.5	15.4
Single crosses			
Newal x Olli	116.6	53.0	14.9
Newal x O.A.C.21	115.8	54.0	14.3
Titan x Trebi	114.8	53.5	13.1
Albert x Olli	113.4	53.5	15.0
Regal x Colsess	108.8	48.0	14.3
Newal x Albert	106.4	53.5	15.2
Wisconsin 38 x Chevron	94.2	54.5	15.1
Velvet x Chevron	81.8	55.0	15.6
Lion x Trebi	79.2	50.0	14.3
Triple crosses			
(Regal x Colsess) Newal	126.4	53.0	14.9
O.A.C.21 (Titan x Trebi)	117.4	53.5	13.6
O.A.C.21 (Newal x Olli)	109.4	53.5	14.2
Double crosses			
(Newal x Olli)(Titan x Trebi)	125.6	53.0	14.8
(Lion x Trebi)(Wisconsin 38 x Chevron)	107.6	54.0	14.3
(Newal x Albert)(Titan x Trebi)	100.6	53.0	14.3
(Regal x Colsess)(Titan x Trebi)	100.2	52.0	14.7
(Regal x Colsess)(Newal x Olli)	94.8	49.0	14.7
(Velvet x Chevron)(Wisconsin 38 x Chevron)	93.4	53.5	15.4

TABLE X (continued)

	Yield (bu.per acre)	Weight (lb.per bushel)	Protein (%)
Five-variety crosses			
O.A.C.21(Lion x Trebi)(Wis.38 x Chevron)	103.8	52.5	14.0
(Velvet x Chevron)(Wis.38 x Chevron)O.A.C.21	97.4	54.0	14.9
Six-variety crosses			
(Lion x Trebi)(Wis.38 x Chev.) Albert x Olli	111.6	53.5	15.1
(Lion x Trebi)(Wis.38 x Chev.) Newal x Albert	104.4	53.5	15.2
(Velvet x Chev.)(Wis.38 x Chev.) Newal x O.A.C.21	82.0	53.5	15.7
(Wis.38 x Chev.)(Lion x Trebi) Regal x Colsess	75.6	53.5	15.1
Minimum significant difference	15.7		

TABLE XI

Analysis of variance for yield of barley hybrid yield test

Variance due to	D.F.	M.S.	F.
Blocks	23	2952.78	1.24
Varieties	35	19392.51	8.12**
Error	85	2389.66	
Total	143		

** Significant to the 1% point

Heterosis in single and multiple hybrid populations

Yield

In the early wheat hybrid yield test, the F_2 bulk hybrids gave a wide range in yield varying from 48.0 to 74.1 bushels per acre (Table XII). All the 43 F_2 hybrid populations displayed hybrid vigor for yield exceeding the parental average in both the single and multiple crosses. Increases varying from 1.1 to 14.7 bushels per acre represented an increase of from 2 to 30 per cent over the mean of the parents. Single crosses gave the highest average percentage increase, whereas the triple crosses had a lower mean increase than either single or double crosses. The triple crosses, however, contained a higher percentage of high-yielding parents, as is indicated by a high mean parental average and, therefore, it would be hardly logical to expect as great an increase over a high parental mean as when two lower yielding parents are involved.

Of the 28 F_2 bulk hybrids in the soft wheat hybrid yield test, all but one, namely Pacific Bluestem x Dicklow, yielded more than the parental average. Results in Table XIII show mean yields of 72.7 and 58.3 bushels per acre for the bulk hybrids and parental averages respectively. The F_2 bulk hybrids show an average increase of 14.4 bushels per acre over the parental average. Mean yields of single, triple, and double

TABLE XII

Comparison of the F_2 yields of single and multiple early wheat crosses with the parental average

	Yield (bushels per acre)					
	F_2	Female parent	Male parent	Par. av.	F_2 minus par. av.	F_2 in % of par. av.
Single crosses						
H-37-30 x Canus	74.1	71.2	60.2	65.7	8.4	113
H-37-30 x 482B	68.2	71.2	42.4	56.8	11.4	120
Canus x Thatcher	65.4	60.2	54.4	57.3	8.1	114
Red Bobs x Master	65.3	66.9	43.2	55.0	10.3	119
Canus x Red Bobs	65.0	60.2	66.9	63.6	1.4	102
H-37-30 x Reward	64.0	71.2	39.8	55.5	8.5	115
Red Bobs x 1515-29.27	63.7	66.9	31.2	49.0	14.7	130
H-29-35 x Reward	61.1	59.7	39.8	49.8	11.3	123
482B x Thatcher	60.5	42.4	54.4	48.4	12.1	125
Red Bobs x Reward	59.5	66.9	39.8	53.4	6.1	111
482B x Regent	53.8	42.4	48.8	45.6	8.2	118
Master x Reward	49.6	43.2	39.8	41.5	8.1	120
Master x Prelude	49.0	43.2	33.0	38.1	10.9	129
Prelude x 482B	48.0	33.0	42.4	37.7	10.3	127
Mean	60.5			51.2	9.3	119

	Yield (bu./ac.)			
	F_2	Par. av.	F_2 minus par. av.	F_2 in % of par. av.
Triple crosses				
(Canus x Thatcher) Red Bobs	69.3	62.1	7.2	112
(H-37-30 x 482B) H-29-35	67.7	58.2	9.5	116
(H-29-35 x Reward) H-37-30	67.4	60.5	6.9	111
(Red Bobs x 1515-29.27) Canus	65.4	54.6	10.8	120
(Canus x Red Bobs) Thatcher	63.7	59.0	4.7	108
(Red Bobs x Reward) Regent	58.6	51.1	7.5	115
(Red Bobs x Reward) Thatcher	56.3	53.9	2.4	104
Mean	64.1	57.1	7.0	112.3

TABLE XII (continued)

	Yield (bu./ac.)			
	F_2	Par. av.	F_2 minus par. av.	F_2 in % of par. av.
Double crosses				
(482B x Thatcher)(H-37-30 x Canus)	68.0	57.0	11.0	119
(482B x Thatcher) (H-37-30 x Reward)	65.5	51.9	13.6	126
(Canus x Thatcher)(Red Bobs x Master)	63.4	56.2	7.2	113
(Canus x Thatcher)(H-37-30 x 482B)	62.6	57.0	5.6	110
(Red Bobs x 1515-29-27)(H-37-30 x Reward)	61.9	52.3	9.6	118
(482B x Thatcher)(Red Bobs x Reward)	60.0	50.9	9.1	118
(482B x Regent)(Canus x Red Bobs)	59.2	54.6	4.6	108
(H-29-35 x Reward)(H-37-30 x 482B)	58.7	53.3	5.4	110
(Master x Canus)(482B x Reward)	58.2	46.4	11.8	125
(Canus x Thatcher)(Red Bobs x 1515-29.27)	57.8	53.2	4.6	109
(Prelude x 482B)(Red Bobs x Reward)	57.6	45.5	12.1	127
(Canus x Thatcher)(Red Bobs x Reward)	57.4	55.3	2.1	104
(Red Bobs x 1515-29.27)(Master x Prelude)	56.0	43.6	12.4	128
(482B x Thatcher)(H-29-35 x Reward)	55.2	49.1	6.1	112
(Prelude x 482B)(Red Bobs x Master)	54.4	46.4	8.0	117
Mean	59.7	51.5	8.2	116.3
Five-variety crosses				
(H-29-35 x Rew.)(H-37-30 x 482B) R.B.	67.0	60.1	6.9	111
(H-29-35 x Rew.)(H-37-30 x 482B) That.	57.3	53.8	3.5	106
Mean	62.2	57.0	5.2	108.5
Six-variety crosses				
(H-29-35 x Rew.)(H-37-30 x 482B) Can. x That.	60.6	55.3	5.3	110
(Can.x That.)(R.B.x 1515-29.27) H-37-30 x Can.	60.5	59.4	1.1	102
(Can.x That.)(R.B.x 1515-29.27) H-29-35 x Rew.	59.7	51.5	8.2	116
(Canx That.)(R.B.x 1515-29.27) Mas.x Rew.	55.2	47.3	7.9	117
Mean	59.0	53.4	5.6	111.2
Eight-variety cross				
[(H-29-35 x Rew.)(H-37-30 x 482B)] x [(Canus x That.)(R.B.x 1515-29.27)]	63.8	53.2	10.6	120
Mean of 43 F_2 hybrids	60.8	52.8	8.0	115
Minimum significant difference	6.0			

TABLE XIII

Comparison of the F_2 yields of single and multiple soft wheat crosses with the parental average

	Yield (bushels per acre)					
	F_2	Female parent	Male parent	Parental average	F_2 minus par. av.	F_2 in % of par. av.
Single crosses						
Dicklow x Onas	82.9	82.7	74.4	78.6	4.3	106
P.B.S. x Onas	81.9	75.0	74.4	74.7	7.2	110
Onas x Prelude	80.2	74.4	34.2	54.3	25.9	148
P.B.S. x Prelude	77.3	75.0	34.2	54.6	22.7	142
P.B.S. x 482B	74.2	75.0	37.1	56.0	18.2	132
Dicklow x 482B	73.4	82.7	37.1	59.9	13.5	122
P.B.S. x Dicklow	66.6	75.0	82.7	78.8	-12.2	84
Onas x 482B	60.6	74.4	37.1	55.8	4.8	109
482B x Master	49.6	37.1	45.4	41.2	8.4	120
Master x Prelude	47.7	45.4	34.2	39.8	7.9	120
Mean	69.4			59.4	10.1	119

	Yield (bu./ac.)			
	F_2	Parental average	F_2 minus par. av.	F_2 in % of par. av.
Triple crosses				
(Dicklow x 482B) Dicklow	83.5	71.3	12.2	117
(P.B.S. x Onas) 482B	78.6	55.9	22.7	141
(P.B.S. x Dicklow) Master	76.2	62.1	14.1	123
(Dicklow x Onas) Master	69.9	62.0	7.9	113
(Dicklow x 482B) 482B	69.4	48.5	20.9	143
(P.B.S. x Onas) Master	67.7	60.0	7.7	113
(P.B.S. x Onas) Prelude	64.0	54.4	9.6	118
(Onas x Prelude) Master	62.2	49.8	12.4	125
Mean	71.4	58.0	13.4	124

TABLE XIII (continued)

	Yield (bu./ac.)			
	F_2	Parental average	F_2 minus par. av.	F_2 in % of par. av.
Double crosses				
(Dicklow x 482B)(P.B.S. x Onas)	82.2	67.3	14.9	122
(P.B.S. x 482B)(Onas x Prelude)	81.6	55.2	26.4	148
(Onas x Prelude)(P.B.S. x 482B)	79.8	55.2	24.6	145
(P.B.S. x 482B)(Onas x 482B)	78.4	55.9	22.5	140
(Onas x 482B)(Onas x Prelude)	78.4	55.0	23.4	142
(Dicklow x 482B)(Onas x 482B)	78.2	57.8	20.4	135
(Onas x Prelude)(Dicklow x 482B)	77.3	57.1	20.2	135
(Onas x 482B)(P.B.S. x Prelude)	75.8	55.2	20.6	137
(P.B.S. x Prelude)(Dicklow x 482B)	70.2	57.2	13.0	123
(482B x Master)(Dicklow x Onas)	68.6	59.9	8.7	114
Mean	77.0	57.6	19.5	134
Mean of 28 F_2 crosses	72.7	58.3	14.4	125
Minimum significant difference	8.8			

crosses exceed the parental average by 19, 24, and 34 per cent respectively. The multiple crosses displayed further increases in vigor over the F_2 yields of the crosses used in their parentage. Many of the double combinations, whose parentage included two high-yielding soft wheats and two early low-yielding hard wheats, gave results quite comparable to single combinations involving two relatively high-yielding soft wheat parents.

In the barley hybrid yield test the F_2 population yields ranged from 75.6 to 126.4 bushels per acre. The results in Table XIV show the F_2 hybrid yields varying from 10.2 bushels per acre below, to 37.1 bushels per acre above the parental average, with a mean increase of 15.7 bushels per acre. Only three out of the 24 F_2 crosses failed to exceed the parental average, and none of these yielded significantly less. Eleven of the remaining 21 crosses gave significant increases over the mean of the parents. The triple and five-variety crosses showed exceptional hybrid vigor and this may perhaps be a good method of intensifying the qualities of the single parent while still retaining the advantages of multiple crosses. Owing to severe lodging at the time of heading, the barley test was not as accurate as the wheat hybrid yield tests. It is quite possible that some of the strong-strawed varieties or hybrids had an advantage, and perhaps the yields of some were reduced owing to second growth. A minimum

TABLE XIV

Comparison of the F_2 yields of single and multiple barley crosses with the parental average

	Yield (bushels per acre)					
	F_2	Female parent	Male parent	Par. av.	F_2 minus par. av.	F_2 in % of par. av.
Single crosses						
Newal x Olli	116.6	110.4	92.0	101.2	15.4	115
Newal x O.A.C.21	115.8	110.4	76.6	93.5	22.3	124
Titan x Trebi	114.8	86.8	81.2	84.0	30.8	137
Albert x Olli	113.4	95.4	92.0	93.7	19.7	121
Regal x Colsess	108.8	93.0	95.6	94.3	14.5	115
Newal x Albert	106.4	110.4	95.4	102.9	3.5	103
Wisconsin 38 x Chevron	94.2	88.2	81.8	85.0	9.2	111
Velvet x Chevron	81.8	74.0	81.8	77.9	3.9	105
Lion x Trebi	79.2	58.0	81.2	69.6	9.6	114
Mean	103.4			89.1	14.3	115

	Yield (bu./ac.)			
	F_2	Par. av.	F_2 minus par. av.	F_2 in % of par. av.
Triple crosses				
(Regal x Colsess) Newal	126.4	102.4	24.0	123
O.A.C.21 (Titan x Trebi)	117.4	80.3	37.1	146
O.A.C.21 (Newal x Olli)	109.4	88.9	20.5	123
Mean	117.7	90.5	27.2	131
Double crosses				
(Newal x Olli)(Titan x Trebi)	125.6	92.6	33.0	136
(Lion x Trebi)(Wis.38 x Chevron)	107.6	77.3	30.3	139
(Newal x Albert)(Titan x Trebi)	100.6	93.4	7.2	108
(Regal x Colsess)(Titan x Trebi)	100.2	89.2	11.0	112
(Regal x Colsess)(Newal x Olli)	94.8	97.8	-3.0	97
(Velvet x Chevron)(Wis.38 x Chevron)	93.4	81.4	12.0	115
Mean	103.7	88.6	15.1	118

TABLE XIV (continued)

	Yield (bu./ac.)			
	F_2	Par. av.	F_2 minus par. av.	F_2 in % of par. av.
Five-variety crosses				
O.A.C.21 (Lion x Trebi)(Wis.38 x Chevron)	103.8	77.0	26.8	135
(Velvet x Chev.)(Wis.38 x Chevron) O.A.C.21	97.4	79.0	18.4	123
Mean	100.6	78.0	22.6	129
Six-variety crosses				
(Lion x Trebi)(Wis.38 x Chev.) Albert x Olli	111.6	85.5	26.1	130
(Lion x Trebi)(Wis.38 x Chev.) New.x Alb.	104.4	90.1	14.3	116
(Velvet x Chev.)(Wis.38 x Chev.) New. x O.A.C.21	82.0	87.5	-5.5	94
(Wis.38 x Chev.)(Lion x Trebi) Regal x Colsess	75.6	85.8	-10.2	88
Mean	93.4	87.2	6.2	107
Mean of 24 F_2 hybrids	103.3	87.9	15.4	118
Minimum significant difference	15.7			

significant difference of 15.7 bushels per acre was required between varieties, indicating a high variability between plots. Nevertheless, the range in yields was sufficient to give significant differences between hybrids or between hybrids and parents.

Heterosis for yield was general in all three field tests. Although increases of the F_2 hybrids over the mean of the parents were not statistically significant in all cases, the fact that only four out of 95 crosses yielded below the average of the parents, and only one of these significantly less, makes it possible to conclude that such increases in yield may be expected in the early generations of wheat and barley hybrids.

If such increases in yield are a part of hybrid vigor in the F_2, the question arises as to how much of this hybrid vigor for yield is maintained in the F_3 generation. Immer (14) with barley hybrids and Harrington (13) with wheat hybrids have both shown a decrease in the F_3 yields as compared with the F_2. In the early wheat bulk hybrid test nine crosses were present in both the F_2 and F_3 generations. Results in Table XV show that all the F_3 crosses yielded significantly lower than the corresponding crosses in the F_2 generation. The decreases in yield ranged from 6.3 to 20.5 bushels per acre and are striking and consistent throughout. The average reduction in yield was 13.1 bushels per acre, representing a loss in yield vigor of 21 per cent.

Eight out of nine F_3 hybrids yielded less than the parental average. Expressed in per cent of the parental average the F_2 and F_3 yields would be 116 per cent and 92 per cent respectively. The results in Table XV also show that the crosses with the greatest amount of hybrid vigor for yield in the F_2 were the ones with the greatest reduction in yield in the F_3. This would be an important consideration if F_2 yields were to be used in the evaluation of hybrid material for selection purposes.

TABLE XV

Comparison of the yields of F_2 and F_3 generation early wheat bulk hybrids

Cross	Yield (bushels per acre)					
	F_2	F_3	Par. av.	F_2 minus F_3	F_2 minus par. av.	F_3 minus par. av.
H-37-30 x 482B	68.2	47.7	56.8	20.5	11.4	-9.1
Red Bobs x 1515-29.27	63.7	45.4	49.0	18.3	14.7	-3.6
H-29-35 x Reward	61.1	45.6	49.8	15.5	11.3	-4.2
Canus x Thatcher	65.4	50.7	57.3	14.7	8.1	-6.6
Master x Reward	49.6	36.5	41.5	13.1	8.1	-5.0
482B x Regent	53.8	41.6	45.6	12.2	8.2	-4.0
Red Bobs x Reward	59.5	49.6	53.4	9.9	6.1	-3.8
H-37-30 x Canus	74.1	66.7	65.7	7.4	8.4	1.0
Canus x Red Bobs	65.0	58.7	63.6	6.3	1.4	-4.9
Mean	62.3	49.2	53.6	13.1	8.6	-4.4
% of the par. av.	116%	92%				

A close relationship exists between the hybrid yields and their parental averages. Immer (14) in a study of F_1 barley yields found that the highest yielding F_1 hybrids came from the parents which had the highest average yields. A highly significant correlation coefficient of .838 was obtained between the early wheat bulk hybrid yields and their parental averages. The correlation surface in Figure 1 shows the distribution of the single and multiple crosses. The single crosses cover a slightly wider range than the multiple combinations. In the single crosses alone even higher correlation coefficients of .886 and .956 exist between bulk hybrid yields and the parental averages for the F_2 and F_3 respectively (Figure 2). The slopes of the regression lines for the F_2 and F_3 points are significantly different to the 5 per cent point. The higher regression coefficient of the F_3 crosses indicates that crosses with low parental averages have had greater reductions in yield in the F_3 generation than crosses with high parental averages.

A significant correlation was obtained for the soft wheat bulk hybrids and their parental averages but it was not as high as the correlation found in the early wheat test. The single crosses again covered a wide range as shown in Figure 3, but the correlation surface for the multiple crosses was inclined to be restricted to the central portion of the scatter diagram.

Since the regression coefficient for the soft wheat test was much lower than that for the early wheat, similar increases in mean parental yield did not result in as great increases in bulk hybrid yield.

In the barley tests the relation between the F_2 yields and the parental average was not so close as in the wheat tests. The points on the correlation surface shown in Figure 4 are very scattered, and although positive correlation coefficients were obtained they were not significant. The scattered arrangement of the points may be due partially to the large experimental error of the barley test.

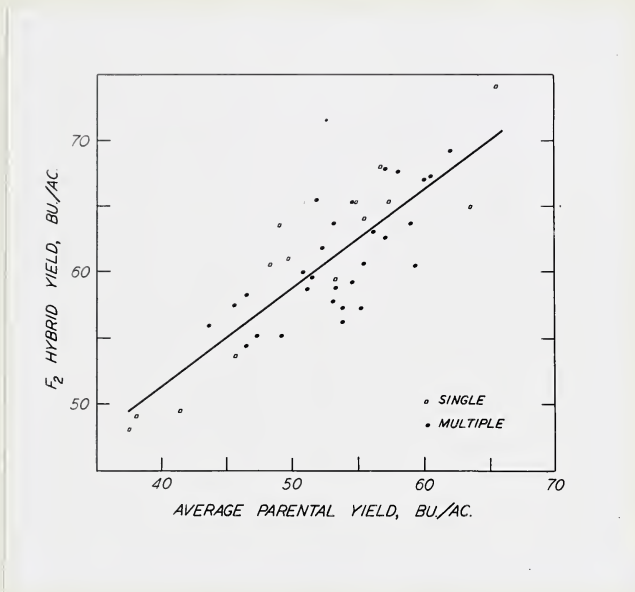

Figure 1

Relation between F_2 hybrid yields and parental averages in the early wheat hybrid yield test

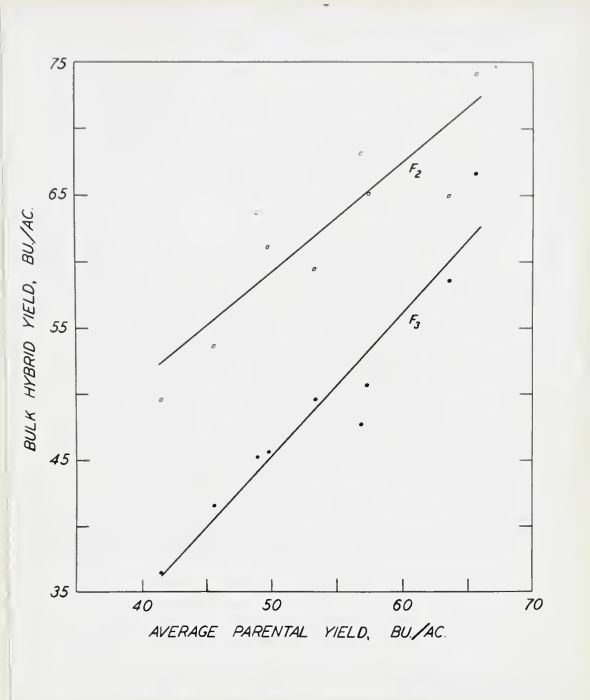

Figure 2

Relation between the yields of nine F_2 and nine F_3 single crosses and parental averages in the early wheat hybrid yield test

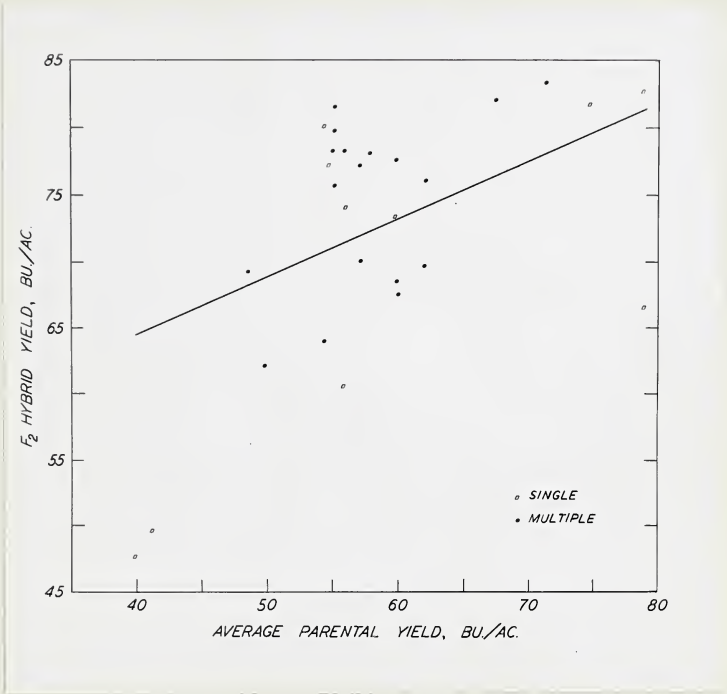

Figure 3

Relation between F_2 hybrid yields and parental averages in the soft wheat hybrid yield test

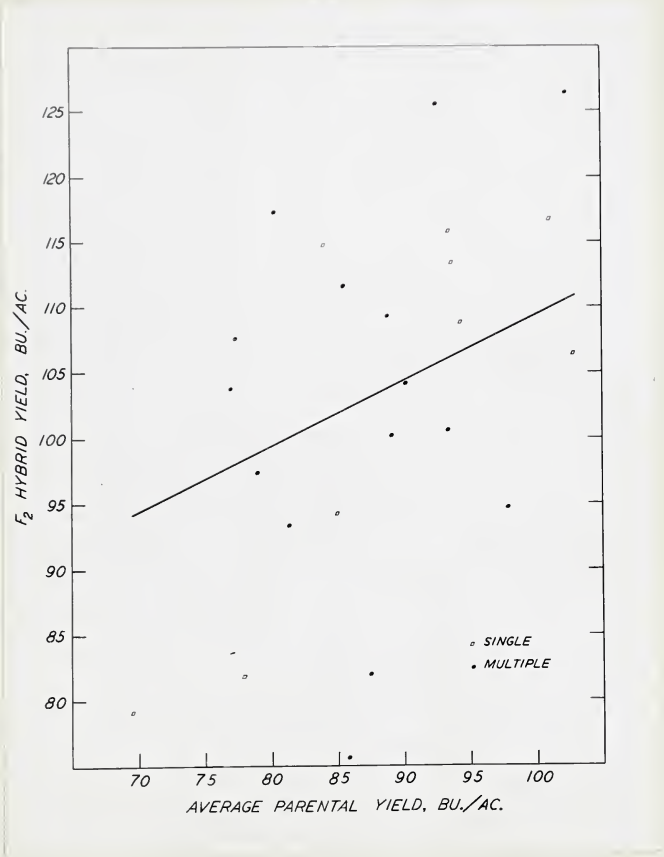

Figure 4

Relation between F_2 hybrid yields and parental averages in the barley hybrid yield test

Earliness

Many workers have shown F_1 hybrids to be earlier in heading and maturity than plants of the parental strains. As mentioned previously Florell (8), and Clark and Hooker (2) found that earliness was dominant in the F_2 and F_3 generations. In the wheat tests the majority of the F_2 hybrid populations reached first head, full head, and maturity before the parental average. Only four out of forty-three early wheat F_2 hybrids were in full head after the mean of the parents and only nine were later in maturity. The F_3 crosses were on the average later maturing than similar F_2 crosses, while six out of nine F_3 hybrids came into full head and maturity later than the parental average.

In most of the single crosses segregates appeared which headed as early as the earlier parent. Some of the multiple combinations gave segregates which were as early as the earliest parent but since the multiple combinations often had a higher proportion of late-yielding varieties in their parentage than the single crosses, it was not unexpected when many failed to give segregates as early as the earliest variety in their parentage. Results in Table XVI show the mean growth period for the different types of crosses as compared with the mean of the parental averages. Differences in days to first head indicate that the multiple crosses

TABLE XVI

Comparison of growth period of single and multiple early wheat hybrids with the parental average

No. of hybrids	Type of cross	Average number of days to First head: Hybrids	First head: Par. av.	First head: Par.av. minus hybrid average	Full head: Hybrids	Full head: Par. av.	Full head: Par.av. minus hybrid average	Maturity: Hybrids	Maturity: Par. av.	Maturity: Par.av. minus hybrid average
14	Single F_2	56.9	58.4	1.5	61.5	62.6	1.1	109.5	110.5	1.0
9	Single F_3	58.3	59.3	1.0	64.4	63.6	-0.8	112.8	111.8	-1.0
7	Triple	58.4	60.1	1.7	64.4	64.8	0.4	112.6	113.4	0.8
15	Double	56.2	58.5	2.3	61.7	62.7	1.0	109.8	110.6	0.8
2	5-variety	58.0	59.9	1.9	64.0	64.7	0.7	112.0	112.8	0.8
4	6-variety	57.3	59.6	2.3	63.6	63.7	0.1	112.5	112.6	0.1
1	8-variety	57.3	59.6	2.3	63.5	64.0	0.5	111.8	112.4	0.6

Table with multiple columns and rows

showed greater deviations from the parental mean than did the single crosses. This is evidence of the wide segregation that may be characteristic of multiple combinations.

Soft wheat multiple combinations also showed greater deviations from the parental mean than did single crosses. Results in Table XVII show that the average date of heading of the first segregate of the double crosses is 4.2 days earlier than the parental average as compared with 2.7 days for the single crosses. It would seem that double crosses should be a good source of early and perhaps high-yielding segregates.

A very high positive correlation coefficient of .991 was obtained between days to full head and days to maturity. This indicates that date of heading is an accurate estimate of earliness and, as it can often be more conveniently secured than the date of maturity, the use of heading notes is a valuable estimate of the growth period required by any variety or hybrid. A lower correlation coefficient of .896 between days to first head and days to maturity indicates the possibility that certain crosses will yield a few very early-maturing segregates.

Highly significant positive correlation coefficients were obtained between yield and days to maturity: .832 for the 11 parents and .720 for the 43 F_2 hybrid populations. The higher yielding crosses are usually

later maturing. However, the correlation is low enough to allow hybrids of equal growth periods to be significantly different in yield. If the hybrids are classified into groups of equal maturity, crosses may be selected with good yield potentialities as well as with certain early maturity prospects.

TABLE XVII

Comparison of growth period of single and multiple soft wheat hybrids with the parental average

		Average number of days to					
		First head			Full head		
No. of hybrids	Type of cross	Hybrids	Par. av.	Par.av. minus hybrid average	Hybrids	Par. av.	Par.av. minus hybrid average
10	Single	57.2	59.9	2.7	62.8	64.3	1.5
8	Triple	55.3	58.7	3.4	61.8	62.6	0.8
10	Double	55.3	59.5	4.2	62.3	64.0	1.7

Height

Increases in plant height in the F_1 wheat hybrids have been reported by Sax (18), Griffee (10), and Rosenquist (17). Results from the wheat tests show that hybrid vigor in the F_2 and F_3 generations is also accompanied by increases in plant height over the parental average. The results in Table XVIII give a comparison of the F_2 and F_3 single early wheat crosses

TABLE XVIII

Comparison of heights of F_2 and F_3 early wheat hybrids with the parental average

Cross	Height (inches)				
	F_2	F_3	Parental average	F_2 minus parental average	F_2 minus F_3
H-37-30 x 482B	59.0	55.7	55.8	3.2	3.3
H-29-35 x Reward	53.5	52.3	50.5	3.0	1.2
Red Bobs x Reward	53.5	53.5	51.1	2.4	0.0
Canus x Thatcher	52.7	49.8	50.7	2.0	2.9
Red Bobs x 1515-29.27	52.3	52.3	50.6	1.7	0.0
482B x Regent	52.5	51.2	50.2	1.3	1.3
Master x Reward	50.2	51.0	49.0	1.2	-0.8
Canus x Red Bobs	53.0	53.5	52.8	0.2	-0.5
H-37-30 x Canus	55.7	54.0	55.6	0.1	1.7
Mean	53.6	52.6	51.8	1.8	1.0

TABLE XIX

Comparison of average heights of single, triple, and double soft wheat hybrids with the parental average

No. of crosses	Type of cross	Average height (inches)		
		F_2	Parental average	F_2 minus parental average
10	Single	56.2	53.6	2.6
8	Triple	55.3	53.0	2.3
10	Double	56.7	53.3	3.4
	Mean	56.1	53.3	2.8

with the parental average. All the F_2 bulk hybrids exceeded the parental average, the average increase being 1.8 inches. The F_3 hybrids were also usually taller than the mean of the parents and at the same time averaged one inch shorter than the corresponding F_2 hybrids.

Greater and more consistent increases over the parental average were found for the soft wheat hybrids (Table XIX). Without exception the F_2 hybrids were taller than the parental average. Mean increases for single, triple, and double crosses were 2.6, 2.3, and 3.4 inches respectively.

Although the significant positive correlation coefficient of .860 indicates a close relation between the height of the early wheat parental varieties and their yield, corresponding correlation coefficients for the hybrids were positive but not significant. This is perhaps due to the small range in height of the hybrids as compared with the relatively greater range in yield.

Weight per bushel

The parents and the hybrids of the early wheat test did not differ greatly in weight per bushel. The F_2 hybrids gave on the average only very small increases over the parental average. Differences between the F_2 and F_3 hybrids were not significant.

In the soft wheat hybrid yield test with greater differences existing between the parents, more variation occurs in the weight per bushel of the hybrids. All 28 F_2 crosses showed increases in weight per bushel over the mean of the parents. Mean increases for the single, triple, and double crosses were 0.9, 1.0, and 1.6 pounds per bushel respectively. Prelude was especially high in weight per bushel and all crosses including Prelude also showed a comparatively high weight per bushel.

Out of 24 F_2 barley crosses 18 showed an increase in weight per bushel over the parental average. Despite the fact that the majority of the crosses showed increases, however, varietal response was not consistent throughout.

Protein content

The early and soft wheat bulk hybrids gave protein percentages that were intermediate between the parents or were very close to the parental averages. The barley hybrid populations had a slight tendency to be lower in protein content than the mean of the parents. Twenty-four F_2 barley hybrids showed a mean reduction from the parental average of 0.4 per cent.

A few of the F_3 early wheat hybrids shown in Table XX had a reduced protein percentage as compared

TABLE XX

Comparison of the protein content of F_2 and F_3 early wheat hybrids

	Protein content (%)			
	F_2	F_3	F_2-F_3	Par. av.
482B x Regent	17.2	17.2	0.0	16.2
Red Bobs x 1515-29.27	15.6	14.1	1.5	16.0
Master x Reward	15.9	15.9	0.0	15.7
H-37-30 x 482B	15.6	15.2	0.4	15.7
Red Bobs x Reward	15.6	15.1	0.5	15.4
Canus x Thatcher	15.3	15.4	-0.1	15.0
H-37-30 x Canus	15.2	14.5	0.7	14.8
H-29-35 x Reward	14.9	15.1	-0.2	14.6
Canus x Red Bobs	14.5	14.6	-0.1	14.6
Mean	15.5	15.2	0.3	15.3

with corresponding F_2 hybrids. As shown by Neatby and McCalla (16) a negative correlation exists between yield and protein. Correlation coefficients for the F_2 early wheat, soft wheat, and barley hybrids were -.567, -.478, and -.406 respectively. If the yield-protein relationship were to be maintained, it would be natural to expect an increase in protein percentage with the marked reduction in yield as found in the F_3. This is not the case, however, and there seems to be a tendency for the F_3 hybrids to have a lower percentage than the preceding generation. With environmental influences as constant as possible for all the hybrids, it might be concluded that this decrease in protein percentage may be due to

the segregation of the multiple genetic factors which determine the relative protein content of each variety.

The correlation surface for protein content and yield of the parental lines and bulk progenies of the early wheat test is presented in Figure 5. Owing to hybrid vigor for yield, the regression line of the F_2 bulk hybrids is much higher on the correlation surface than the regression line of the parents or the F_3 hybrid populations. The parental variety, H-29-35, with a low protein content of 13.1 per cent made a large contribution to the steep slope of the parental regression line. All parental varieties do not contribute equally to the hybrids and this may account for the difference in slope of the regression lines of the parental and hybrid populations.

The results in Figure 6 show the relationship of protein and yield in the F_2 soft wheat bulk hybrids as compared with the parents. Although the regression coefficient for the parents is higher than in the early wheat test, the F_2 hybrid populations give a lower regression coefficient. The very high correlation coefficient of -.983 between protein and yield, obtained for the parents, may be somewhat misleading. The high correlation value is due to the small number of points in the population and to the grouping of the three soft wheat parents at one extreme and of the three early parents at the other.

The results for the barley bulk hybrids and parental varieties shown in Figure 7 form a very scattered correlation surface. These results would hardly provide a good basis for prediction purposes.

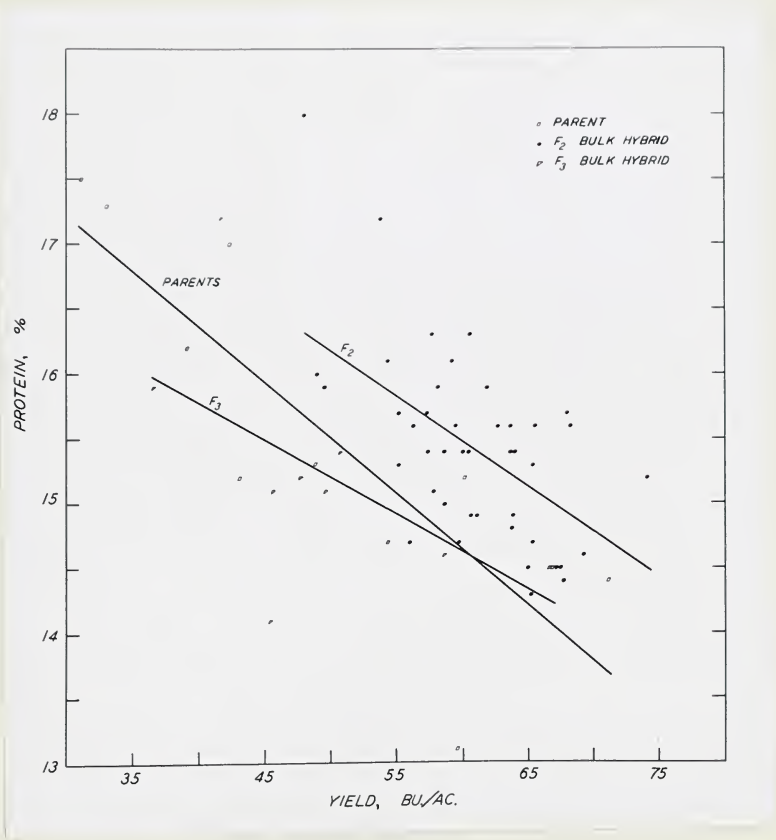

Figure 5

Relation between protein and yield in parental lines and bulk hybrids of the early wheat hybrid yield test

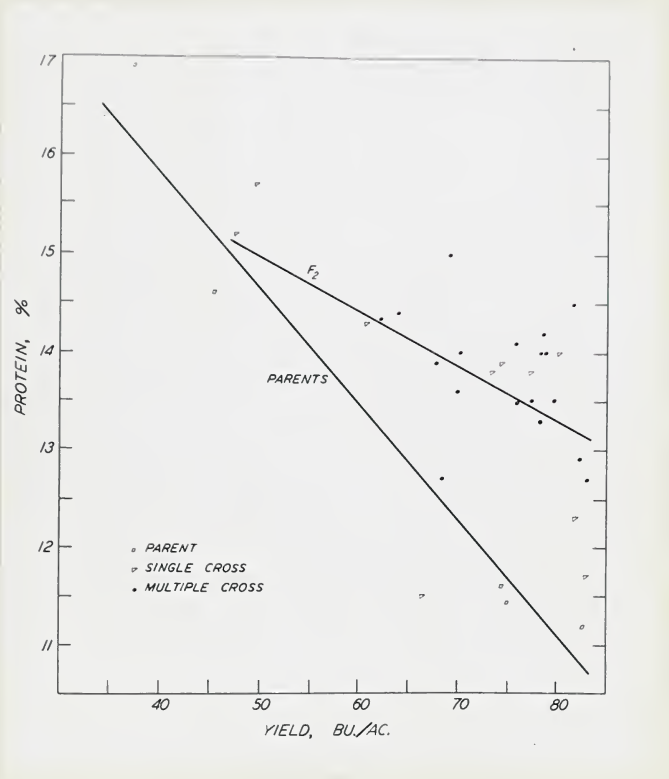

Figure 6

Relation between protein and yield in parental lines and bulk hybrids of the soft wheat hybrid yield test

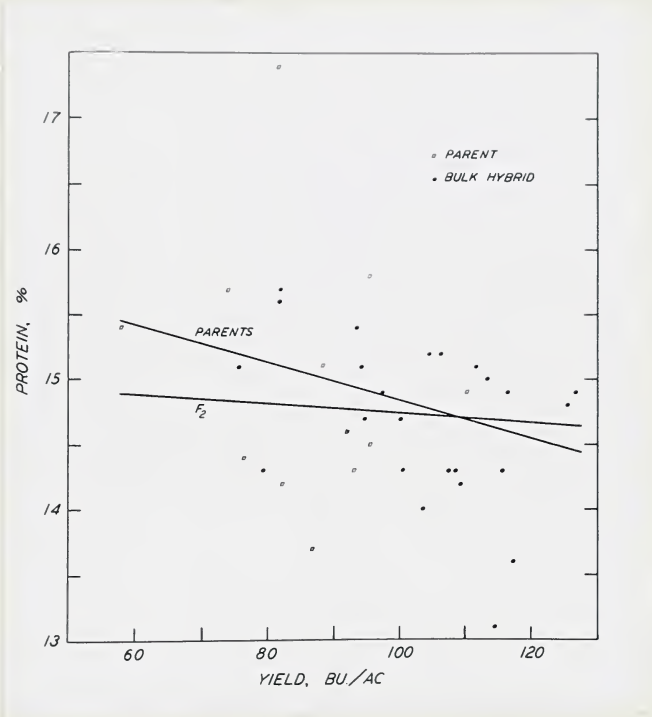

Figure 7

Relation between protein and yield in parental lines and bulk hybrids of the barley hybrid yield test

Genetic relation and heterosis

Many studies have indicated that hybrid vigor is dependent on genetic differences in the parents. East and Hayes (5) and later East (4) showed that the amount of heterosis in an F_1 plant is roughly proportional to the genic differentiation of the two parental stocks. Harrington (12) with F_2 wheat hybrids found that the amount of heterosis was dependent on the genetic differences of the parental varieties.

In the early wheat test a comparison of the yielding ability of single crosses with both closely and distantly related parents is possible. The single early wheat crosses are arranged in Table XXI, in order of the estimated closeness of their parental genetic relationship. In the first cross, the parents, Canus and Thatcher, are very closely related whereas the parental varieties in the succeeding crosses are pregressively more distantly related. The last three crosses have parents which are related only very distantly if at all. It would appear that the first three crosses, each with closely related parents, have shown less heterosis for yield as compared with crosses with more distantly related parents. With the exception of H-37-30 x 482B, however, the first three crosses have the highest average parental yield. Perhaps it is not reasonable to expect as great an increase over a high parental average as when two low-yielding parents are involved. By comparing crosses with equal parental averages it can be seen that

H-37-30 x 482B with unrelated parents shows more hybrid vigor than H-37-30 x Reward or Canus x Thatcher, both of which have closely related parents. No other comparisons show appreciable differences in hybrid vigor.

In the barley hybrids, very few of the varieties used as parents are related. In Table XXII, however, two crosses in particular have closely related parents, namely Titan x Trebi and Newal x O.A.C. 21. Trebi is a parent of Titan and O.A.C. 21 is a parent of Newal. These two closely related crosses showed the greatest increases in hybrid vigor of all the single crosses. The suggestions of East (4) and of Harrington (12) are not, therefore, supported by these results.

TABLE XXI

Comparison of the amount of heterosis in F_2 early wheat crosses having both closely and distantly related parents

Cross	Yield (bu./ac.) F_2	Parental average	Increase (%)
Canus x Thatcher	65.4	57.3	14
H-37-30 x Canus	74.1	65.7	13
H-37-30 x Reward	64.0	55.5	15
H-29-35 x Reward	61.1	49.8	23
Master x Prelude	49.0	38.1	29
Master x Reward	49.6	41.5	20
Prelude x 482B	48.0	37.7	27
H-37-30 x 482B	68.2	56.8	20
482B x Regent	53.8	45.6	18
482B x Thatcher	60.5	48.4	25

TABLE XXII

Comparison of the amount of heterosis in F_2 barley crosses having both closely and distantly related parents

Cross	Yield (bu./ac.) F_2	Parental average	Increase (%)
Titan x Trebi	114.8	81.2	37
Newal x O.A.C.21	115.8	93.5	24
Newal x Olli	116.6	101.2	15
Albert x Olli	113.4	93.7	21
Regal x Colsess	108.8	94.3	15
Newal x Albert	106.4	102.9	3
Wis. 38 x Chevron	94.2	85.0	11
Velvet x Chevron	81.8	77.9	5
Lion x Trebi	79.2	69.6	14

Combining ability of the parents

As stated in the introduction it was hoped that these yield tests with hybrids might give some information as to the relative value of the parents for crossing purposes. Despite the number of crosses, only a limited number of comparisons was possible. In the early wheat bulk hybrid test, the single crosses were not complete--that is, one variety was crossed with only four others--and in the comparison of any two parents there were only one or two matings in common. For example, in the comparison of H-37-30 and Red Bobs in Table XXIII, it would appear on the basis of four crosses that H-37-30 gave higher yielding offspring than did Red Bobs.

TABLE XXIII

Comparison of H-37-30 and Red Bobs in crosses with Canus and Reward

	F_2 yields (bu./ac.)	
Parents	Canus	Reward
H-37-30	74.1	64.0
Red Bobs	65.0	59.5
Difference	9.1	5.5

Similar limited comparisons are available for some of the other varieties. A study of the early wheat bulk hybrids shows that the yield of the parental varieties is a valuable indication of their combining ability. Crosses of

the soft and hard wheat varieties show the parent soft wheats--Dicklow, Onas, and Pacific Bluestem--to be equal as parents. In the barley test, however, the relatively small number of barley crosses studied made it impossible to evaluate the large number of parental varieties.

DISCUSSION

Hybrid vigor for yield has been found in almost all the hybrid bulk populations studied in the F_2 generation. As this study did not include an investigation of individual plants, it is not possible to attribute increases in yield to definite plant characters. Immer (14) made a detailed study of heterosis and reports that six F_1 barley hybrids as an average exceeded the mean of the parents by 8.3 per cent in number of heads per plant, 11.1 per cent in seeds per head, and 4.9 per cent in weight per seed. It is quite probable that these three factors in varying proportions are responsible for the hybrid vigor in the present study.

It has been impossible in this short study to determine whether the yield of early generation bulk populations can be used to evaluate crosses for future selection purposes. If the findings of Harlan et al (11) and Harrington (12) are accepted, however, it would seem possible to make a preliminary evaluation of many of the crosses included in bulk hybrid yield tests. Despite the range in yields it would be hard to make a close estimate of the yielding potentialities of each cross on the basis of one F_2 yield test. For prediction purposes a rough classification might be set up in which the F_2 hybrids could be placed in three groups, and these would include promising, average, and unpromising crosses.

If F_2 bulk population yields alone are to be used as a basis for discarding low-yielding crosses, it seems

important to determine the amount of hybrid vigor present. Results in Table XV show a definite tendency for crosses with a large amount of hybrid vigor in the F_2 to have the greatest decreases in yield in the F_3 generation. The limited number of comparisons in this study seems to indicate that the amount of heterosis may be a valuable aid in predicting F_3 yields. Therefore, it seems worth while to include the parental varieties in any test of F_2 bulk hybrids in order that some estimation may be made of the amount of hybrid vigor involved in the F_2 yields.

Owing to the fact that certain crosses show more reduction in yield in the F_3 than others, it would seem that the results of two generations would be required to give a good estimate of the true yield potentialities of a hybrid population. If the bulk hybrids were allowed to segregate in the F_2 and yield tests were conducted in the F_3 and F_4 generations, a more accurate evaluation of the hybrids as a source of high-yielding segregates might be obtained. Yield tests of the F_3 and F_4 would be less complicated by hybrid vigor and the yields obtained would represent to a greater degree the actual yields of the segregates themselves. If a bulk hybrid were high yielding in the F_3 and F_4 there must have been a good proportion of high-yielding segregates making up that particular population. Another advantage of delaying the yield tests until the F_3 would be that it would give an opportunity to secure sufficient seed for a fully replicated yield test.

Notes on days to head or mature, strength of straw, height, weight per bushel, and protein percentage would be a valuable addition to yield data. They would be especially important in evaluating crosses from parents about which relatively little is known, or if the crosses were being tested in areas where the parents are not commonly grown.

The segregation of the multiple crosses for earliness indicates the possibilities for wide segregation in other characters such as yield. A study of the hybrid vigor of multiple combinations in the F_3 would be worth while. It would give information particularly as to whether the decreases in yield which accompany increasing homozygosity in multiple crosses are as great as those found in single crosses.

The pronounced heterosis shown by the soft wheat hybrid populations, especially the multiple combinations, may have been due to the distantly related parental varieties involved. In the early wheat crosses, with relatively closely related parental varieties, the amount of heterosis in the multiple combinations was considerably less. It would seem that the difference in genetic relationship would account for the variation in hybrid vigor.

Limited comparisons within the early wheat test indicate that the above relationship still exists although complicated by differences in the yield levels of the parents. The opposite tendency is shown in the single barley crosses where crosses with closely related parents show more hybrid

vigor than those with distantly related parents.

Results of the present study seem to indicate that in general the amount of hybrid vigor is dependent upon the closeness of the genetic relation of the parents. In a comparison of individual crosses within tests, however, the relation between genetic disparity and heterosis is not consistent.

The small number of comparisons available limited any definite conclusions in regard to the combining ability of the parental varieties. If the crosses were complete--that is, each variety combined with each other variety--then averages might be worked out to show the amount of yielding ability each parent contributed to its resultant crosses. However, as far as the hybrids of the early wheat test have shown, the combining value of the parents may be represented by their relative yielding ability. In the soft wheat parental comparison, no one of the soft wheat parents was consistently better than another. These limited results show the importance of having crosses complete to give adequate comparisons for parent evaluation.

SUMMARY

In order to study the behavior of single and multiple crosses in early generations as compared with their parents, replicated yield tests were conducted in the green-

house and the field. In the greenhouse, 24 hard wheat F_1 multiple combinations were arranged in a preliminary test. Three separate field tests consisted of parental varieties with the following hybrids: 52 early hard wheat crosses; 28 combinations of hard and soft wheats; and 24 barley crosses. With the exception of nine F_3 early hard wheat crosses all the unselected bulk hybrids in the field tests were in the F_2 generation.

The greenhouse test gave a good indication of what might be expected of the multiple crosses in the F_2. There was a significant positive correlation between the F_1 greenhouse yields and the F_2 field yields, while the correlation coefficients for days to head, days to mature, and height were all highly significant.

In the field, on the average, the F_2 hybrid population exceeded the parental average in earliness, height, and weight per bushel. The protein content of the hybrids was intermediate between the two parents but was not consistently above or below the parental average. The F_3 crosses were on the average slightly later in heading and maturity, shorter in straw, and reduced in protein content.

Hybrid vigor for yield was found in almost all of the F_2 hybrids. Only four out of 95 crosses yielded below the average of the parents and only one of these significantly less. Multiple crosses on the average showed at least as much hybrid vigor as single crosses. In the soft wheat bulk

hybrid test, mean yields of single, triple, and double crosses gave average increases of 19, 24, and 34 per cent respectively over the parental average, showing maximum increases in yield in the double crosses.

The F_2 hybrid populations gave wide differences in yield. If yield tests of bulk hybrid populations in the early generations are used to evaluate crosses as a source of high-yielding segregates, then certain low-yielding crosses may be discarded as definitely unpromising.

The F_3 early wheat bulk hybrids showed a mean reduction in yield of 13.1 bushels per acre as compared with the F_2 yields of the same crosses, representing a loss in vigor of 21 per cent. Some of the F_2 hybrids showing the greatest increases in yield over the parental average had the greatest reduction in yield in the F_3. For prediction purposes it would seem unwise to place too much confidence in the results from the F_2 generation.

The pronounced heterosis shown by the multiple crosses of hard and soft wheats may have been due to the combination of distantly related parents. In the early wheat single crosses, however, the variation in genetic relation of the parents alone would not account for the differences in hybrid vigor; and in the single barley crosses, those bulk hybrids with closely related parents showed the most hybrid vigor.

In the wheat tests a close relationship existed between F_2 yields and the parental average. The yields of the

parents were a good indication of the combining ability of the varieties used in this study.

ACKNOWLEDGEMENTS

The writer wishes to express his thanks to Dr. A. G. McCalla, Professor of Field Crops, University of Alberta, under whose direction this work was conducted, for his helpful suggestions and criticisms during the progress of the investigation; to Dr. J. W. Boyes, formerly Assistant Professor of Genetics and Plant Breeding, Department of Field Crops, University of Alberta, under whose guidance this study was commenced; and to the National Research Council of Canada and the Canada Malting Company, Limited, for financial assistance.

REFERENCES

1. CLARK, J.A. Segregation and correlated inheritance in crosses between Kota and Hard Federation wheats for rust and drought resistance. Jour. Agr. Res. 29: 1-47. 1924.

2. CLARK, J.A. and HOOKER, J.R. Segregation and correlated inheritance in Marquis and Hard Federation crosses, with factors for yield and quality of spring wheat in Montana. U.S.D.A. Bull. 1403. 1926.

3. COFFMAN, F.A. and WIEBE, G.A. Hybrid vigor in oats. Jour. Amer. Soc. Agron. 22:848-860. 1930.

4. EAST, E.M. Heterosis. Genetics. 21:375-395. 1936.

5. EAST, E.M. and HAYES, H.K. Heterozygosis in evolution and in plant breeding. U.S.D.A. Bur. Pl. Ind. Bull. 243:1-58. 1912.

6. EAST, E.M. and JONES, D.F. Inbreeding and Outbreeding. Philadelphia and London, J.B. Lippincott Co. 1919.

7. ENGLEDOW, F.L. and PAL, B.P. Investigation on yield in cereals. VIII. Hybrid vigor in wheat. Jour. Agr. Sci. 24:390-409. 1934.

8. FLORELL, V.H. Studies on the inheritance of earliness in wheat. Jour. Agr. Res. 39:333-347. 1924.

9. GOULDEN, C.H. Modern methods of testing a large number of varieties. Dom. of Can. Dept. of Agr. Tech. Bull. 9. 1937.

10. GRIFFEE, F. Comparative vigour of F_1 wheat crosses and their parents. Jour. Agr. Res. 22:53-63. 1921.

11. HARLAN, H.V., MARTINI, M.L. and STEVENS, H. A study of methods in barley breeding. U.S.D.A. Tech. Bull. 720. 1940.

12. HARRINGTON, J.B. Predicting the value of a cross from an F_2 analysis. Can. Jour. Res. 6:21-37. 1932.

13. HARRINGTON, J.B. Yielding capacity of wheat crosses as indicated by bulk hybrid test. Can. Jour. Res. C, 18:578-584. 1940.

14. IMMER, F.R. Relation between yielding ability and homozygosis in barley crosses. Jour. Amer. Soc. Agron. 33:200-206. 1941.

15. JENKINS, B.C. Unpublished data. 1942.

16. NEATBY, K.W. and McCALLA, A.G. Correlation between yield and protein content of wheat and barley in relation to breeding. Can. Jour. Res. 16:1-15. 1938.

17. ROSENQUIST, C.E. Hybrid vigour in wheat. Jour. Amer. Soc. Agron. 23:81-105. 1931.

18. SAX, K. Sterility in wheat hybrids. Genetics. 6:399-416. 1921.

19. THOMPSON, W.P. Earliness in wheat and its inheritance. Sci. Agr. 1:193-198. 1921.

B29750